Deriving Economic Development Benefits of Transit Projects from Integrated Land Use Transportation Models

Review of Models Currently Used in the U.S. and Recommendations

final

report

prepared for

Federal Transit Administration, Office of Planning and Environment

prepared by

Cambridge Systematics, Inc.

with

Dr. John Gliebe

April 8, 2009

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100 CambridgePark Drive, Suite 400
Cambridge, Massachusetts 02140

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1.0 Introduction

On October 17, 2007, the Federal Transit Administration (FTA) convened an expert panel to discuss methods for evaluating the economic development benefits of transit projects.[1] FTA hoped to develop, to the extent possible, a standardized, empirically-based, and rational method for evaluating the potential economic development benefits of project proposals in the FTA Section 5309 Major Capital Investment Program ("New and Small Starts"). Members of the panel were charged with recommending one or more methodologies for further research, development, and testing that could be applied to forecast the economic development impacts, and the associated benefits, of major transit capital investments. One of the panel's recommendations was to:

- *Identify state of the art integrated transportation-land use models being used in practice and identify the strengths and weaknesses of each model for forecasting transit-induced land use changes and economic benefits. Pursue a limited number of case studies using these models, to evaluate the impacts of different types of transit investments on economic development under different policy and market conditions.*

This report responds to this recommendation by investigating the suitability of existing transportation-land use models to fulfill FTA's objectives. In particular, the report discusses the relative merits of various integrated land use-transportation model systems currently being used by metropolitan planning organizations (MPO) or regional transit agencies for the purpose of deriving the economic development benefits of proposed fixed-guideway transit projects. The primary objective is to identify those agencies with advanced modeling practices that might be considered suitable for case studies.

Suitability depends on the extent to which a given model's design is sensitive to the measures needed by the Federal Transit Administration (FTA) to assess economic development benefits. Beyond theoretical suitability, an additional consideration is the extent to which each model system has been tested and used in agency operations, with a particular emphasis on studies involving fixed-guideway transit projects. As a secondary objective, this report also investigates the range of model structures and parametric specifications found in these models, with the ultimate goal being to derive a standard set of structural and parameter values for the development of an economic development benefits calculation tool.

Based on the findings of the review, it is clear that integrated transportation – land use models currently are not widely used in transportation planning

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[1] *Measuring the Economic Development Benefits of Transit Projects: Proceedings of an Expert Panel Workshop.* Prepared by Cambridge Systematics, Inc. for FTA Office of Planning and Environment, March 2008.

practice. Furthermore, those few agencies that have implemented such models have not yet applied them in corridor- or project-level planning studies. Consequently, the ability of these models to evaluate the economic development benefits of individual transit projects remains unproven and requires considerable additional research and empirical testing. In addition, given the time and resources expended by a transportation planning agency to develop a new transportation forecasting model, it does not appear reasonable at the present time for FTA to expect New Starts grant applicants to use integrated transportation – land use models to evaluate the economic development benefits of proposed transit projects.

For these reasons, FTA and the consultant team concluded that existing models are not capable of fulfilling FTA's objectives of reliably evaluating the economic development benefits of individual transit projects. Therefore, FTA chose not to pursue case studies with any of these models at the present time. However, this report does lay out some recommended enhancements to transportation-land use models that could potentially make them more suitable for transit project evaluation in the future.

The remainder of this report includes the following sections:

- Economic development benefits accruing to transit projects;
- Questions to ask of integrated land use transportation models;
- Recommended model evaluation criteria;
- Typology of integrated land use transportation models implemented in the U.S.;
- Reviews of agency models;
- Summary of findings on model structures;
- Usefulness of current integrated land use transportation models for evaluating transit projects; and
- Recommended enhancements.

2.0 Economic Development Benefits Accruing to Transit Projects

The first step in developing criteria for the evaluation of integrated land use transportation modeling systems is to define what constitutes an economic development benefit in the view of FTA.

The role of transportation as a catalyst in economic development is in improving travel times and costs. User benefits are typically derived directly from these travel time and costs savings. In order to avoid double counting, direct travel time and cost savings should not be included as an economic development benefit of a proposed transit project. However, it is proper to count as benefits certain multiplier effects that result from the travel time and cost savings to users. Specifically, the travel time and cost savings may increase the access of users and nonusers to activity opportunities and to markets, reducing their overall costs and disposable income, which will in turn induce additional spending. This increase in consumer spending will then result in business growth, particularly in the retail sector, which may respond with higher wages, providing additional disposable income, and/or hiring more workers. In addition, businesses may respond by increasing land development activity to accommodate growth and to take advantage of competitive advantages in market access. If new development or redevelopment results in a more compact urban form than would otherwise occur, particularly one oriented around transit stations, then further improvements to market access will follow. Further evidence of the value of this increased accessibility will be changes to both residential and commercial property values. All else being equal, the greatest gains in value will be realized by the properties that gain the most in terms of accessibility.

In summary, many of the measures economists point to as evidence of economic development – higher wages, regional job growth, increased tax revenues, construction activity, and property values – have a common root in accessibility changes.

3.0 Questions to Ask of Integrated Land Use Transportation Models

Given that accessibility changes attributable to transit projects are important, there are several questions we should answer regarding the design and specification of integrated land use transportation models.

How do we measure accessibility?

Accessibility is measured in several different ways within integrated land use transportation models. In practice, specifications will vary between modules of the same land use model system as well as across implementations, even for the same general model structure. In addition, accessibility may be measured at both the regional level and the local level.

At the regional level, land use models typically represent an origin zone's "access to population/households" using a negative exponential-impedance decay function multiplied by the number of households in each analysis zone, summed over all potential destination zones. This is shown in the equation below in which theta (θ) represents the marginal utility of the impedance measure.

$$A_i^{HH} = \sum_j HH_j * \exp(-\theta c_{ij})$$

Impedance, the cost of travel between zone i and all other zones j, written as c_{ij}, may be expressed through travel times (usually auto) or mode choice log-sums. A similar regional measure is typically applied to estimate "access to employment," summing impedance-weighted jobs rather than households. Sensitivity to travel costs will depend on the context of the measurement. Impedance-weighted measures of accessibility to activity opportunities may represent one of several economic constructs, such as:

- Value to Households and Residential Land Developers
  - **Job Market Opportunities –** Access to total employment (or basic employment) with a low sensitivity to travel costs.
  - **Retail Market Opportunities –** Access to retail employment, (or nonbasic employment) as a proxy for nonwork activity opportunities, with a high sensitivity to travel costs.
- Value to Businesses and Commercial Land Developers
  - **Labor Market Accessibility –** Access to population/households (workers) with a low sensitivity to travel costs.

- **Customer Market Accessibility –** Access to population/households (customers) with a high sensitivity to travel costs.
- **Agglomeration Effects –** Access to employment of the same or complementary industry types, both suppliers and consumers, with a high-sensitivity to travel costs.

Other regional measures of accessibility include straight-forward measures of travel time to a central business district or airport, which may be valued by either households or businesses.

An alternative measure of regional accessibility is trip-weighted accessibility, where the idea is to provide a more direct link to the results of the travel model. In the equation below, the relevant variable is home-based work trips, T_{ij}, and Γ_{ij} represents the log-sum composite utility of travel between zones *i* and *j* from the mode choice model.

$$A_i^{HBW} = \frac{\sum_j \left(T_{ij}^{HBW} * \Gamma_{ij} \right)}{\sum_j T_{ij}^{HBW}}$$

Finally, another common approach is to simply use mode choice model log-sums to derive the composite utility of zone *i* to all other zones *j*, without using a trip weight or an attraction variable such as population or employment.

$$A_i^{HBW} = \sum_j \left(\Gamma_{ij} \right)$$

At the local level, measures of accessibility may include distance or travel time to the nearest highway interchange or to the nearest transit station or stop. Other models include variables such as the number of retail jobs within a prespecified travel time or distance buffer. Agglomeration also may be captured in land use models by simple measures such as the total employment of a complementary industry type within a prespecified travel time or distance buffer.

Where do measures of accessibility appear in land use models and how should they be analyzed?

In land use models, accessibility measures are specified as explanatory variables in models of residential, workplace, and business location choices. They also may be used in a separate model that represents real estate developer choices/ decisions whether to develop or redevelop land for a particular use and at a specific level of intensity. Accessibility measures also may be specified in a hedonic pricing model as a contributing factor in determining property values, and these land value calculations may in turn be specified as variables in residential and business location choice models. Thus, it would seem that either hedonic pricing models or location choice models could be used to measure the economic development benefits of transit projects, but not both.

In addition, care must be taken to distinguish the effects of travel time/cost improvements from the efficiency gains of resulting spatial rearrangement of households and jobs. Travel time and cost improvements already are counted as a part of user benefits calculations; therefore, unweighted accessibility measures similar to those described above should not be counted directly as an economic development benefit. The increment in value or utility that results from increased access to activity opportunities and markets is capitalized in the response of the development community through the spatial rearrangement of land uses, presumably in a way that will lead to even greater efficiencies. It is these incremental efficiency gains that we need to capture.

What weights do we assign to accessibility in the overall benefits calculation?

The answer to this question should come from the estimation or calibration of the model itself. If random utility models are used, then the parameter specifications should provide the marginal contribution of each additional unit of accessibility, however measured, to the choice situation at hand. For example, a residential location choice model with an estimated coefficient on accessibility to total employment provides a measure of the elasticity of spatial allocation propensity with respect to a change in job market opportunities. This same discrete choice model structure can accommodate multiple measures of accessibility in the same utility function, permitting different coefficient weights for each measure. The implication, of course, is that we should expect estimated/calibrated coefficients to have values consistent with acceptable elasticity ranges, to be determined.

What else should we consider besides accessibility?

An additional consideration is whether land development changes resulting from a transit project are attributable to improved accessibility or to other factors.[2] Other factors might include the direct effects of transit-supportive land use policies, such as zoning and other land use plan changes, and developer incentives such as tax breaks and reduced impact fees. Secondarily, developers may decide to take advantage of the cost savings and amenities provided by transit, such as provision of streetscaping and other complementary infrastructure surrounding station areas, security, lighting, and trash removal. Finally, developers also may react to the political momentum of a large transit project. If transit and transit-oriented development is promoted and made attractive enough, the conceptual appeal to the public may carry enough promise to motivate some developers to invest in transit-supportive designs, which may have a snowball effect as other developers become eager to grab their own piece of the pie.

None of these effects, however, is necessarily attributable to any quantifiable change in accessibility. Since what we observe in terms of location choice utilities is the result of both accessibility and other qualitative or nonmeasured factors, it is important that an integrated land use model distinguish regional

[2] Discussion of "other factors" was derived from: Polzin, Steven E., "Transportation/Land – Use Relationship: Public Transit's Impact on Land Use," *Journal of Urban Planning and Development*, 125(4), December 1999, pp. 135-151.

accessibility from transit station area effects on the utilities of residential, workplace, business, and developer choices. This implies that the location choice models should include both accessibility variables and, to the extent possible, variables that represent transit supportive zoning, location-specific subsidies, and other qualitative station area effects. Leaving station area effects out of location choice utility equations or land value calculations is likely to lead to specification error and an overstatement of the positive contributions of accessibility.

What is the proper metric for evaluating the economic development benefits of transit projects – changes in utility derived from discrete choice models or changes in land values derived from hedonic price models?

Both discrete choice models, grounded in random utility theory, and hedonic pricing models are supported in the economics literature; however, there are several reasons why changes to utility may be the better option. First, as a practical matter, many integrated land use models do not use linear hedonic regression models for land values, but derive land values in other ways. For example, equilibrium land use models, discussed later in this report, derive land prices as the outcome of balancing supply and demand for different development types by solving systems of simultaneous linear equations.

In contrast, discrete choice models representing location choices are used in all of the integrated land use transportation models that based their design on economic theory. As discussed below, however, some of these models are based on an aggregate decision paradigm while others are based on disaggregate decision models.

In either case, by measuring and compiling changes to composite utilities between no-build and build scenarios, as represented by changes to the log-sum values of discrete choice models, we can derive theoretically valid measures of changes to welfare resulting from a proposed project. As shown in the equation below, we can express this in terms of compensating variation (CV). The beta in the equation is a normalizing coefficient that transforms the difference in composite utility into a monetary unit, and CV represents the amount of money that persons would be willing to receive in the "no-build" scenario in order to be as well off as in the "build" scenario.

$$CV = \frac{1}{\beta_{\cos t}}\left(\ln\left[\sum_{\mathrm{j=1}}^{J} \exp\left(v_i^{\mathrm{Build}}\right) \right] - \ln\left[\sum_{\mathrm{j=1}}^{J} \exp\left(v_i^{\mathrm{No\ Build}}\right) \right] \right)$$

This is essentially the same formula used by FTA to calculate user benefits, in which the normalizing parameter is the in-vehicle travel time coefficient from the mode choice model. In a land use model, the choice of a normalizing coefficient may be different and should be subject to more in depth study. In addition, these welfare changes may have different economic interpretations, depending on the model. For example:

- **Residential Location Choice –** Changes to Consumer Surplus;
- **Business Location Choice –** Changes to Producer Surplus; and

- **Real Estate Development Choice –** Changes to Economic Rents.

What spatial units of analysis are required to obtain good measures of economic development benefits resulting from transit projects?

As discussed below in the review of operational land use models, land use models often operate at a different level of spatial resolution than the travel model to which they are linked. For example, the traditional equilibrium models allocate development, households, and businesses at larger spatial units due to practical constraints on the availability and quality of employment data as well as computational considerations. To derive economic development benefits for transit projects, land use model should use spatial units of analysis that are fine-grained enough to account for land development near transit stations, preferably at varying distances so that the benefits of proximity can be distinguished from the nuisance effects of being "too close" to a transit station.

Further, if there is an insufficient supply of developable land surrounding a transit station, development is unlikely to occur, an outcome that may be obscured if zone sizes are too large. Finally, it is important that station area effects be attributed to zones in proportion to the spatial extent of their impacts. That is, a single light rail station would not be expected to have the same marginal impact on the utility of locating in a very large zone as it would in a smaller zone.

What time scales are required to obtain good measures of economic development benefits resulting from transit projects?

Integrated land use transportation models have been developed to respond in different ways to the passage of time. For example, some equilibrium models are structured without path dependency, such that they predict a single-shot horizon-year forecast, starting from a distant base year. In contrast, other models make path dependency explicit, simulating land development on an annual basis and inserting travel model runs at 5- or 10-year intervals. The implications of these different treatments of time are that real estate development choices, which control the pace of urban (re)development, will have estimated/calibrated coefficients that reflect the propensity to make land development decisions over the time interval. Household and business "move or stay" decisions will be similarly tuned to time scales. This of course makes direct comparison of model coefficients for models calibrated to different time intervals nearly impossible. Additional research may be required to determine whether path dependency has a nonlinear effect when projected over a long forecast horizon, and whether the size of the intervals selected for the exchange of inputs and outputs with the travel model makes an appreciable difference.

In general, the response of the land development community to design, assemble resources, and begin construction on a project in response to a change in market conditions is thought to be three to five years. The difficulty in generalizing this notion is that some developers react not to the actual stimulus, such as a change in transportation system accessibility, but rather to the prospect of it occurring, which might result in what appears to be a nearly concurrent response. This is further complicated by the state of the macroeconomy, which may accelerate or dampen the amount of speculation that occurs. Accordingly, there does not seem to be an accepted theoretical basis for developer response rates with respect to transportation system changes.

Are there exogenous factors that might affect modeled economic development benefits resulting from transit projects?

The introduction of transit alone is not enough to spur development without sufficient demand for new development, or without a sufficient supply of developable land. As discussed above, new development or redevelopment in the vicinity of transit stations is unlikely to occur without a sufficient supply of developable land, which should be handled by the model's spatial accounting mechanism. In addition, if a regional economy is expected to stagnate, the introduction of transit may not be enough to spur new development. Demand for new development or redevelopment is typically handled in land use models by exogenous, regional control totals for both households/population and employment by industry classification. With one notable exception, discussed below, most integrated land use transportation models assume exogenous macroeconomic inputs.

Regional control totals usually are based on official forecasts developed at a state or county level and assumed to be immutable for the purposes of modeling. Consequently, the theoretical economic benefits of net regional job creation as the result of a large public infrastructure project need to either be incorporated directly into the control totals or assumed not to exist. Thus, the economic benefits we should expect to measure from the application of an integrated land use transportation model are limited to efficiency due to spatial reallocation.

4.0 Recommended Model Evaluation Criteria

For each model system under consideration, it is important to identify how the model system treats the following important elements of the model structure and specification. The set of model evaluation criteria listed below follows directly from the discussion above on how economic development benefits are, or should be, represented in integrated land use transportation modeling systems.

- Regional Accessibility Measures
  - Household Access to Job Opportunities;
  - Household Access to Nonwork Activities;
  - Business Access to Labor;
  - Business Access to Customers;
  - Business Agglomeration Effects; and
  - Travel Costs to Major Destinations.
- Local Accessibility Measures
  - Highway Interchange Access;
  - Transit Station Access; and
  - Other Quantitative Measures.
- Station Area Effects
  - Zoning;
  - Tax Policies/Impact Fees;
  - Parking Facilities; and
  - Other Qualitative Attributes.
- Approach to Land Value Estimation
- Specification of Random Utility Models
  - Household Location Choice;
  - Workplace Location Choice;
  - Business Location Choice; and
  - Land Development Choice.
- Spatial Units
- Time Scales
- Exogenous Inputs/Controls

5.0 Typology of Integrated Land Use Transportation Models

The models reviewed for this study include those thought to be relevant to the estimation of economic development benefits accruing from transit projects. Accordingly, this report focuses on those models that have an explicit economic component and is limited to models currently being used by metropolitan-level planning agencies in the U.S. Notably, this leaves out the most ubiquitous land use modeling program used by MPOs, DRAM/EMPAL, primarily because it is viewed as essentially noneconomic in nature and is limited by its inability to consider important policy variables. DRAM/EMPAL is a spatial allocation model that allocates households by demographic characterization and employment by sector to transportation analysis zones through a mechanistic balancing process, very much like the familiar gravity model.

The models reviewed here are all based on economic theory and generally are considered to be the state of the art. Importantly, these models assign an economic value to the accessibility provided by a region's transportation system and possess at least the potential, depending on variable specification, to consider the economic worth of multiple measures of both regional and local accessibility in combination with other attributes. In addition, all of the models reviewed here have some type of market clearing mechanism, in which supply and demand for housing and commercial space are influenced by market prices (land values).

For the sake of exposition, we can characterize land use models along a several dimensions. Below are some of the common ways in which the developers of the models distinguish their designs.

Aggregate versus Disaggregate – Aggregate models may be thought of as "top-down" models because they attempt to balance land use supply and demand at a macro (usually regional) level. There are several variations on this theme, but in each the value of land is the outcome of prices generated to balance supply and demand, either by solving a large set of simultaneous equations, or through a spatial input-output model, described below. The essential point is that aggregate models determine and allocate households, employment and building space in aggregate quantities to spatial units.

In contrast, disaggregate models take a "bottom-up" approach and also may be described as "agent-based." These models view decision-making from the point of view of individual households, businesses, and land developers and depend on some type of hedonic pricing model to derive land values. Discrete choice models are used in both aggregate and disaggregate model systems. Just as they are with travel models, discrete choice models may be applied at an aggregate level to forecast fractional probabilities or at a disaggregate level to simulate individual choices.

Static versus Dynamic – Static models may be thought of as "single shot" models because they start from a set of base conditions and forecast directly to a horizon-year. In contrast, dynamic models are those that explicitly model path dependency, typically by producing forecasts for simulated years, with each subsequent year pivoting off the results of the previous.

Equilibrium versus Disequilibrium – Equilibrium models solve for a unique solution using large sets of simultaneous equations and, accordingly, are always aggregate and static in nature. Disequilibrium models always involve simulation methods, meaning that they can predict multiple outcomes for the same set of inputs, depending on random number seeding. Disequilibrium models may be aggregate or disaggregate, and may be static or dynamic. Critics of the disequilibrium approach point to a lack of a market clearing mechanism to properly predict price signals.

Transportation Embedded versus Transportation Linked – Developers of what we will describe here as "transportation embedded" models consider their systems to be the only truly "integrated" land use transportation models and eschew the use of the term "integrated" when used to describe other, more loosely coupled systems. Transportation embedded systems describe a family of models originally conceived at the Martin Centre of Cambridge University in the U.K., all of which are centered on the concept of spatial input-output regional economic models (see description below under PECAS). These models are necessarily aggregate in nature and include transportation accessibility directly into the calculation of economic production and consumption by spatial units, which is then translated into activity flows between zones, both commercial and noncommercial. Household and business locations are determined directly from the allocation of these activity flows. Among these transportation embedded models are the MEPLAN and TRANUS models which have been used mostly in non-U.S. cases, but also have been used for special studies in the U.S. MEPLAN was used for the recent Sacramento Blueprint Study (regional growth management and scenario visioning), and TRANUS has been tested in Baltimore and was used for early studies conducted by the Oregon Department of Transportation in developing their statewide model, which is based on similar concepts.

Another model system that may be considered to be transportation-embedded is the series of models developed by Alex Anas and associates, beginning with CATLAS in Chicago and later evolving into MetroSim, which also was tested by agencies in Pittsburgh and Houston in the 1990s. These models appear to have fallen out of use in these locations, but a more advanced version has been recently implemented in New York and is described below. These models incorporate transportation accessibility directly into a system of equations in which both household and job locations are determined simultaneously.

Transportation linked systems include most other types of known models, including both aggregate and disaggregate systems, in which the land use model may be run in standalone mode and simply exchanges inputs (travel cost) skims and outputs (predicted zonal households and jobs) with a separately developed travel model.

6.0 Review of Agency Models

The following integrated land use transportation modeling systems have been reviewed and are describe below. They are identified by types, as discussed above.

6.1 METROSCOPE

Developer: In-house (Sonny Conder and Dennis Yee)

Type: Aggregate, Equilibrium, Static, Transportation-Linked

Installations: Oregon Metro, Portland

Description

MetroScope starts with exogenous regional employment forecasts by industry type generated by an independent, regional econometric model; total regional households by household size, income, age, and presence of children (360 HIAK categories); and an initial estimate of land supply and building stock from Metro's regional land information system. The model runs at five-year intervals, exchanging data with the travel model at each interval, although it was originally designed to run as a single-shot horizon forecasting model. MetroScope's primary components are the nonresidential and residential land use models, which interact with each other and a linked trip-based travel model. A "land filter" procedure is used to indicate how much vacant land will be made available in each land use zone and is based on an interpretation of existing municipal zoning codes and expert judgment, usually in consultation with local policy-makers. This is especially important for land at the edge of the urban growth boundary. State law requires that a 20-year supply of developable land be maintained in an urban reserve, but expansions of this supply are often subject to controversy.

For each of 15 industry types, the *nonresidential model* calculates total floor space requirements by building type, multiplied by the number of employees, to arrive at a total demand for floor space by building type, adjusted by prices of 6 different real estate types. Next the model chooses the location of space demand for each industry type from among the 72 employment zones. The model is actually a direct demand equation which estimates the demand in square feet for nonresidential real estate type k by industry type i in zone j as a function of total regional employment in industry type i, the percentage of employment in industry type i that chooses real estate type k when the price ratio (price/cost) is equal to one, the square feet per employee required by industry i in real estate type k when the price ratio is one, the price ratio in zone j for real estate type k, and three types of accessibility measures:

- Access to all employment;
- Access to employment in similar industries; and
- Access to households.

The general form of the variable is given in the example equation below:

- Access to all employment in 20 selected zones

$$AllEmpAcc_i = \frac{\sum_{j=1}^{20} \left(AllEmp_l / acres_l\right)\left(B_{1i} Time_{jl} + B_{2i} Time_{jl}^2\right)^{-1}}{\sum_{l=1}^{20} \sum_{j=1}^{20} \left(AllEmp_l / acres_l\right)\left(B_{1i} Time_{jl} + B_{2i} Time_{jl}^2\right)^{-1}}$$

Using mathematical programming, the difference between the supply and demand of each real estate type is minimized by adjusting prices up or down, as appropriate. The model then calculates new land prices, land consumed, and floor-to-area ratios (FAR) for each employment zone.

The supply side of the model then determines whether and how much floor area should be added to or removed from the supply of available floor space by building type. This is done for each employment zone by comparing the land area available for commercial, industrial, and institutional types, stratified by FAR, and calculating price ratios. As the price for demand exceeds the cost of production, more floor area is added and densities increase. As the price for demand falls below the cost of production, floor area is reduced and densities decrease. The supply model is structured as a system of simultaneous linear equations. New construction is added to "vintage" nonresidential supply.

The *residential model* begins with each joint category of HIAK assigned to an employment zone representing the workplace of a primary worker in the household. For households without workers, this represents a service area. In general, the assumption is that households must be linked in some way to employment; however, it would appear that this initial assignment does not discriminate by HIAK, assuming a uniform distribution across all employment zones. The proportions of households that own or rent (tenure) and building type (single-family, multifamily) and one of eight equally sized consumptions bins, corresponding to housing size and value, are calculated as a function of HIAK based on Year 2000 values. For each HIAK category, tenure type, building type, and consumption bin, and given the assigned employment zone, one of 425 residential zones (census tracts) is chosen using a multinomial logit model. Utility specifications include:

- Price of choice;
- Price of complement;
- Price of anticomplement;
- Travel time (auto) to employment zone;
- Neighborhood amenities score (static); and
- Child-friendly neighborhood score (static).

Total residential zone utility is found by multiplying the utility expression by the number of housing units currently existing in the residential zone that fall into each chosen consumption bin, such that zones without housing units in the chosen consumption bin are not considered.

Residential prices at this stage are an index variable constructed from a relationship between the demand and supply for each consumption bin. The housing supply model then calculates the cost of constructing housing units for each consumption bin, based on house and lot size, costs per square foot by residential zone, and, including any development subsidies. The ratios of prices to costs are then used to adjust prices of each consumption bin for each residential zone in order to balance supply and demand.

Each land use model is run for 50 iterations and then exchanges data with the other land use model. Interaction between employment locations and household locations work through the use of accessibility to households in the choice of nonresidential zones and through the location of household-supportive employment in the location choices for residences. These data exchanges happen twice, after which the two land use models are considered to be in equilibrium, and the data is passed to the travel model, which runs for a set number of iterations. This completes a single five-year interval. Note that iterations are purposely fixed so as to provide repeatable results for the same set of starting inputs.

Implicitly, land use model responses to transportation level of service are lagged five years. According to the developer, elasticity of location choices with respect to a change in travel times range from.25 to.50, which he considers to be small but accurate within the range of standard inputs for a linear model system.

Status

Metro has developed MetroScope in house over the past 10 years and has used it routinely as part of their growth management and long-range land use forecasting operations since 2001. With a dedicated staff of three to five persons involved throughout its development, it has been extensively tested, refined, and rigorously calibrated at the subregional level. Metro has used MetroScope for scenario modeling for a couple of high-profile policy issues, such as the compact growth "centers" concept and scenario modeling for alternative urban growth boundary policies, including analysis of two contentious state ballot measures. In terms of transportation projects, however, it has only been used to produce zonal level forecasts as static inputs to the Metro trip-based travel model.

Until very recently, the land use and demographic forecasting group operated separately from the transportation forecasting group. Thus, MetroScope itself has never been used to evaluate transit alternatives. MetroScope has its own reduced version of the travel model in which mode choice percentages have been fixed in order to reduce run time. The model runs at five-year intervals and uses a reduced multitiered zonal structure for land use allocation, with an ad hoc suballocation procedure used to forecast to the TAZ level. Due to recent agency reorganization, however, the land use and demographic forecasting staff has joined the transportation forecasting group and have plans to increase the fidelity of the system by moving to a TAZ-based system. The Metro travel model now operates on a 2036-zone system. If requested, Metro would be willing to participate in a case study and has provided semicomplete documentation of model specifications.

Contact: Sonny Conder

6.2 NYMTC LUM

Developer: Alex Anas and Associates

Type: Aggregate, Equilibrium, Static, Transportation-Embedded

Installations: New York Metropolitan Transportation Commission (NYMTC)

Description

NYMTC LUM is designed to be run in a single time step and in that sense is a static model. As implemented, however, it has been set up to run in five-year increments, with the outcome of each increment used as the basis for starting the next five-year interval. It is an extremely large land use model, which maintains 3,586 zones to match the agency's travel model system.

NYMTC LUM's three primary inputs are base-year land use, transportation network costs, and horizon-year forecasts of basic employment. Basic employment for the region comes from an exogenous socioeconomic forecasting process. Basic employment is defined in the model as categories of employment that locate independently of other changes in the region, which generally describes any type of industry in which the products or services are not consumed locally, exceptions being education, government and healthcare. Nonbasic employment describes industries that are more sensitive to local changes, such as retail and certain service-sector jobs.

In the first stage of the model, interzonal accessibilities derived from mode choice log-sums are used in the joint choices of residences and workplaces by households. Households also will choose housing types and a bundle of nonwork trips that relate to their residence-job locations. In the second major stage of the model, these nonwork trip bundles result in the calculation of demand for nonbasic employment. These residential location and nonbasic employment additions then lead to adjustments in the supply of developed land. This step leads to a third phase in which accessibilities are recalculated, and the process begins again with another wave of housing and nonbasic employment created. The model iterates until increments in housing and nonbasic employment become negligible.

More formally, NYMTC LUM is composed of a work-residence linkages submodel and a residence-nonwork linkages submodel. A third submodel is responsible for building stock adjustments, a fourth submodel is used to calculate market values, and yet another submodel is used to adjust the supply of jobs in each zone. In addition, the entire system is linked to NYMTC's tour-based travel model, which provides the composite mode-choice impedances used to calculate accessibility values.

The *work-residence linkages submodel* is structured as a nested logit in which the upper level represents the choice of housing type and residence zone and the lower level represents the choice of a workplace zone. This joint choice is constrained by the supply of available jobs on the work end and the supply of available housing units on the residential end. These constraints are adjusted in housing market and labor market submodels, described below. The residential location choice utility specifications include each zone's "cost of accessibility to jobs" and weighted average travel costs, G_{ij} to Manhattan zones, which are calculated as follows:

$$CA_j = \sum_i \frac{E_i^{0.5}}{\sum_n E_n^{0.5}} \ln\left(1 + G_{ji}\right)$$ *where,* E_i represents employment in zone i.

$$TTM_j = \frac{\sum_{i \in \text{Manhattan}} T_{ji} G_{ji}}{\sum_{i \in \text{Manhattan}} T_{ji}}$$ *where,* T_{ji} represents work trips to Manhattan zones i.

Other variables specified included dummy variables for housing type (SF/MF), county-specific dummy variables, and the natural logs of both housing stock and rent.

The *housing market submodel* accepts as inputs the existing supply of housing in each zone and the demand for housing produced by the work-residence linkages submodel. It then equilibrates supply and demand, producing a market clearing price.

The *labor market submodel* starts with an exogenously determined supply of basic-sector jobs (industrial and office) in each zone from the work-residence linkage submodel and the derived demand for nonbasic employment (retail and service) from the residence-nonwork linkages submodel. It then equilibrates supply and demand for nonbasic employment in each zone by adjusting incomes and derives the demand for nonbasic employment in each zone. This module also determines commercial rents in each zone by deriving the demand of commercial space and equilibrating it with supply.

The *residence-nonwork linkage* submodel determines the number of nonwork trips for each zone-to-zone interchange, based on travel impedances, accessibilities, incomes, and other socioeconomic characteristics of the residents. These trips are intended to imply the demand for nonbasic (retail and service sector) land use types and employees. The allocation of nonbasic jobs is formulated as a multinomial logit model, which may be interpreted as the probability of a business choosing to allocate a job to a particular workplace. The utility equations of these models are specified to include both accessibility to regional total employment as well as accessibility to regional population, both using the familiar negative exponential impedance-weighted formula described in the first section of this report.

The purpose of the *market values submodel* is to calculate the profitability of land development and to update the market prices of residential and commercial real estate. The *building stock adjustment submodel* uses the market values as inputs to increase or decrease the supply of housing units and commercial floor space relative to the base-year stock of each type. The form of the model also is a multinomial logit in which the decision to construct or demolish buildings comprise the choice alternatives. Due to lack of longitudinal data, transition constants were developed through trial and error. The range of elasticities varied from.10 to.80 for construction and from.05 to.30 for demolition, varying by location.

The model iterates through each of these submodels until a simultaneous equilibrium is achieved for labor and housing markets, land use patterns, and residence-nonwork linkages. In order to achieve this, the model needs to simultaneously solve several thousand submarket equations, the actual number of which is a function of the number of zones and the classification of housing and jobs within each zone. The model also is constrained by county-level control totals for total employment and total households. Municipal zoning regulations are necessarily generalized to function within a TAZ system by setting minimum and maximum amounts of land and building units of a particular type for each zone.

Status

NYMTC received the land use model from the developer in 2003. Since that time, the model has not been integrated operationally with the New York Best Practices Model (NYBPM) tour-based travel model due to the complexity of the latter tool and the focus on its development rather than that of the land use model. Thus, the two models have not been calibrated as an integrated system and NYMTC LUM has not been used to evaluate any transit projects. In fact, it seems that the land use model has not been used at all by the MPO, which continues to rely on a simpler accounting process for forecasting TAZ-level socioeconomic data. The NYMTC LUM has apparently been used by the New York State Department of Transportation on two studies with "satisfactory results." If selected, NYMTC would be willing to participate in a case study and has provided what seems to be mostly complete documentation of model specifications.

Contact: Ali Mohseni

6.3 Production, Exchange, Consumption, and Allocation System (PECAS)

Developer: HBA Specto (Doug Hunt and John Abraham)

Installations: Sacramento Area Council of Governments (SACOG)
San Diego Association of Governments (SANDAG)
Baltimore Metropolitan Council (BMC)

Type: Aggregate, Disequilibrium, Dynamic, Transportation-Embedded

Description

PECAS represents the most recent incarnation of the long line of spatial input-output (I-O) models mentioned above. A statewide version of the PECAS model has been developed for the Oregon Department of Transportation and a more recent one is planned for the Caltrans. PECAS is implemented in a microsimulation environment and is considered to be a dynamic disequilibrium model, with each simulated year providing the starting conditions for the subsequent simulated year. Equilibrium conditions are not a part of the process. Rather, PECAS represents a continuously evolving relationship between market forces, and the simulation stops when the horizon-year has been forecast.

The model system starts with regional control totals for total employment by industry type and total households by demographic strata, and travel model skims. At the core of PECAS is the spatial I-O model, an economic model that describes the relationships between industries and households in the regional economy. The outcome of a spatial I-O model is a four-dimensional array in which we know the amount of a commodity produced by one industrial sector that is consumed by each other industry sector, which land use zones produced the commodity, and which land use zones consumed the commodity. In PECAS, a fifth dimension is the market exchange location, which may or may not be the same location as consumption, but is used for deriving more accurate commodity flow relationships. The first two dimensions are typically derived from national or state-level I-O tables, which provide technical coefficients, sometimes referred to as "make and use" coefficients, that specify what portion of final demand value is attributable to the consumption of input commodities. In PECAS, households represent both factors of production as labor and consumers of final demand. In addition, land is viewed as an input to production and a commodity to be consumed.

The spatial I-O concept is operationalized in PECAS through the *activity allocation* module (AA), which produces flows of economic activity to and from industry sectors, including households, from one spatial zone to another. Prices are calculated at the zonal level in order to balance the amounts bought and sold, using a mathematical programming algorithm. Location choice models in the form of multinomial logit models are used as part of this process to select destinations for exchange, resulting in a final allocation of households and employment by industry type to each land use zone. It is in AA that household location choices are represented. Although good documentation is not available, it would appear that this is where both regional and local accessibility variables would come into play, including any transit supportive land use policies or neighborhood effects. Economic welfare changes are theoretically obtainable from changes to the composite utilities of these models. Location choice probabilities consider the availability of housing units and commercial floor space in each zone. From the information available, it appears that the choice of exchange locations is the one place in the model system where accessibility variables have been specified in the form of travel times/distances and composite utilities (logsums); however, this is by no means a limitation of the model design.

Next, a *space development* module (SD) is used to create housing units and floor space to accommodate households and jobs in each land use zone in response to the price signals computed in AA. In turn, the resultant allocation of housing units and floor space will be used in the following simulation year to inform AA's location choice models. As land use zones are maintained at a fairly aggregate level, SD in its most recent form is designed to allocate housing units and commercial floor area to smaller spatial units, namely parcels. This is achieved through the specification of a nested logit model in which the upper level represents the choices of no change, changing the type of space or changing the quantity of space, subject to the underlying zoning regulations. The lower level of the model is formulated as a continuous logit which is used to predict the quantity of space demanded, again subject to zoning restrictions.

The results of this process are then fed into a linked transportation model, which also provides travel time and cost skims used to calculate the accessibility variables used in location choice model specifications. Commodity flows between zones are translated into activity flows and eventually commercial trips. This completes one simulated model year. The simulation continues until the final horizon year has been simulated. It should be noted that the utility equations in the SD model currently are based only on transition constants at the upper level and on a sampling of usage intensity at the lower level. Parcel-level land values (rent) equations are specified to account for density and age of structures, but do not seem to have an accessibility component in current specifications.

Note: Many of the coefficient values for the AA and SD modules of PECAS are derived through a calibration process. They are not estimated from disaggregate data, but are formed and adjusted through a multistep iterative process, with modules first being calibrated individually, and then recalibrated together as a system. Consequently, the final coefficient values will not be determined until the final calibration step.

Status

SACOG

SACOG currently is at the stage of calibration and training, with the current schedule showing completion by the end of April 2009. After calibration and training have been completed, they plan to do extensive sensitivity testing by rerunning existing long-range transportation and land use plan scenarios using PECAS in concert with their four-step travel model, SACNET. When operational, the activity allocation module of PECAS will operate using a 650 land use zone system, composed of groupings of TAZs, and will exchange data with the travel model using three- to five-year intervals. In the base year, SACOG uses 1,300 TAZs in its travel model and forecasts land use to 650,000 parcels. SACOG's new activity-based model, SACSIM operates at a parcel level and currently requires off-line manipulation of certain data inputs, such as bus stop locations; thus it currently is not a good candidate for a path-dependent integrated model system. It is worth mentioning the SACOG uses a land use scenario modeling tool, PLACE^{3}S in conjunction with SACSIM, to store and manipulate land use data at the parcel level. Because they are still in this early stage of model development with PECAS, SACOG does not feel that they would make a good candidate for a case study within the near future and does not have any available documentation on model specifications.

Contact: Gordon Garry

SANDAG

SANDAG is using a different approach in developing its PECAS model. The agency has begun with a limited set of commodity and industry types and a greatly reduced set of zones for the first phase of development. The idea here is to calibrate the model system gradually, adding greater stratification of industry and commodity types as well as spatial units with each subsequent phase. The first phase achieved calibration in summer 2008, starting with just seven land use zones, ten household types and 10 industrial sectors. Phase 2 is planned for completion in January 2009 and will include more zones, household types, and industrial sectors. The third and final phase is slated for completion in fall 2010, with the current design calling for 150 zones, 20 to 30 household types, and 80 industrial sectors. Since calibration, testing and specification refinement are at an early stage, model documentation covering parameter values is not available. For these same reasons, SANDAG would prefer not to participate in a case study at this time.

Contact: Ed Schafer

BMC

BMC is following the same phased model development strategy as SANDAG and is now in the midst of their second phase of calibration. Since calibration, testing and specification refinement are ongoing, model documentation covering parameter values is not available and BMC would prefer not to participate in a case study at this time.

Contact: Jamie Bridges

6.4 URBANSIM3/PRE-OPUS

Developer: Center for Urban Simulation and Policy Analysis, University of Washington (Paul Waddell and Alan Borning)

Type: Disaggregate, Disequilibrium, Dynamic, Transportation-Linked

Installations: Oahu Metropolitan Planning Organization (OMPO)

Houston-Galveston Area Council (HGAC)

Wasatch Front Regional Council (WFRC)

Description

UrbanSim is an agent-based dynamic, disequilibrium simulation of urban development. In plain language, the program represents individuals (agents) as households, employers and developers, and simulates their decisions through time (dynamic). As a disequilibrium model, it does not converge to single solution but rather seeks to represent a system that is constantly evolving. The simulation outputs represent the state of the system at the time the simulation is stopped, with results saved at the end of each simulated year. The typical setup exchanges inputs and outputs with a linked travel model at five-year intervals.

UrbanSim is organized around three basic actors: households, employers, and developers. The behavior, or decisions, made by these actors are represented by analytical modeling components, which are each run once during a simulated year. These decisions are simulated for each year of analysis; thus the program steps through time in one-year increments. In the first three generations of UrbanSim, grid cells were used as the spatial units of analysis, which provided some computational advantages, but also obscured certain important distinctions as discussed below.

UrbanSim simulates urban development by considering three primary types of decision-makers as endogenous to the system, while accounting for other influences on urban growth and development through exogenous inputs. The internal decision-makers are households, employers, and developers. These actors are physically represented in model design by three data structures: households, jobs, and grid cells. Each of these data structures possesses both static and dynamic attributes. Static attributes are characteristics of the household, the job, or the grid cell that are set at the start of the simulation and that do not change throughout the simulation. Dynamic attributes are characteristics that may change as the result of model outcomes.

From an economic perspective, households and jobs represent *demand* for the use of land, as manifest in their location at a particular grid cell. Grid cells are means of accounting spatially for the *supply* of land, which is manifest in quantities of residential units and/or nonresidential floor area. The balance between supply and demand is reflected in the land use model through two grid cell measurement variables – land price and accessibility – which affect and are affected by decisions made by households, employers, and developers.

Households and jobs are generated with each simulated year in order to match regional control totals by household type and industry sector, respectively. In addition, for each simulated year, households and jobs have the option to relocate. For each household or job that is added to the simulation or that "decides" to relocate, a location choice model is applied. Location choice models in UrbanSim3 are specified as multinomial logit models. A typical UrbanSim3 specification for *residential location choice* would include the following attribute variables in the expression describing the utility of a location alternative:

- Cost-to-income ratio;

- (Log) residential units within walking distance interacted with household size;
- (Log) industrial square feet within walking distance interacted with income;
- (Log) commercial square feet within walking distance interacted with income;
- (Log) residential units within walking distance stratified by 0 and 1 auto households;
- (Log) accessibility to regional employment stratified by 0, 1, and 2+ auto households; and
- (Log) accessibility to subregional employment stratified by 0, 1, and 2+ auto households.

It should be noted that accessibility to employment and accessibility to households were calculated using the negative exponential formulation discussed above, using log-sum impedances stratified by household auto ownership level. Accessibilities are calculated at the TAZ level, with grid cells inheriting the accessibility value of the TAZ to which it belongs. The *employment location choice model* varies by one of 14 industry sectors and includes the following parameters:

- (Log) available job locations (space);
- Average land value per acre within walking distance;
- Basic sector employment within walking distance;
- Residential units within walking distance;
- Same sector employment within walking distance;
- Retail sector employment within walking distance;
- Service sector employment within walking distance;
- (Log) accessibility to regional population;
- (Log) distance to nearest highway;
- (Log) distance to nearest arterial;
- Travel time to airport;
- Travel time to CBD;
- "Near highway" dummy variable; and
- Development type constants.

UrbanSim3's *land value model* was formulated as a hedonic linear regression model, which predicts price as a function of property attributes and the ratio of a grid cell's current vacancy rate relative to the structural vacancy rate for the region. Property attributes in a typical specification include: development and plan (zoning) type dummy variables, presence of environmental attributes, land use mix variables, and may include some of the following accessibility-related variables:

- (Log) accessibility to regional population;
- (Log) accessibility to regional employment;
- (Log) accessibility to subregional population;
- (Log) accessibility to subregional employment;
- (Log) residential units within walking distance;
- (Log) residential total employment within walking distance; and
- (Log) distance to nearest highway.

UrbanSim3 also has a land development module which uses a multinomial logit formulation to predict transitions from one development type and intensity to another. A typical specification would include transition constants, attributes of surrounding land uses, and the following attributes of interest:

- "Near highway" dummy variable;
- (Log) distance to nearest highway;
- (Log) distance to nearest arterial;
- Regional accessibility to employment; and
- Land value (from land value model).

The model specifications discussed above are "typical" and are a composite of variables found in whole or in part in the three applications discussed below. In addition, it is worth mentioning that the effects of zoning and other government policies can be incorporated directly into the attributes of grid cells. In addition, UrbanSim enables users to override the more market-oriented standard models through user-specified development events or land use policy events. This would, for example, allow for the insertion of a large development change due to the attraction a major regional employer, or to gradually change zoning at specific locations for specific simulation years.

Status

OMPO

OMPO was the first major metropolitan area to investigate UrbanSim as its future land use forecasting tool, participating in the development of the first three generations of the program's development, and working through many data development and software problems. It was not until 2006, though, that they had a fully integrated, calibrated, and validated model. The land use model runs annually and exchanges inputs and outputs with the trip-based travel model at five-year intervals. Despite this achievement, OMPO has not used the integrated model in any of its official transportation planning activities, primarily because the City-County of Honolulu's Department of Planning and

Permitting (DPP) has not sanctioned the results produced by the model. While the model is considered to be calibrated and validated at a regional level, DPP is interested in making further model improvements that will enable it to more closely match planning district totals for households, employment, and built area. There is additional concern that Oahu's unique regional economy and patterns of development – including resorts, tourist attractions, military installations, and agricultural lands – are not well represented in the current specification, which is viewed as too generic to be useful for many planning studies, including planning for transit-oriented development. There are plans to enhance the model by using smaller spatial units than the current 150-meter grid cells, redefining development and building typologies to better suit their needs, and re-estimating and calibrating the various model components. This enhancement is planned for 2009, following modernization of DPP's land information system. In addition, this will likely require an upgrade a conversion to UrbanSim4. If asked by FTA to participate in a case study, OMPO would be willing to do so and has provided complete documentation of its current land use model specification.

Contact: Lori Arakaki

HGAC

HGAC began working with UrbanSim in 2000 and now has a "working model" based on the UrbanSim3 design. In its current form, UrbanSim is integrated with HGAC's trip-based travel model, which now runs at five-year intervals. Previously, they conducted a variety of experiments, including a regional transportation plan (RTP) with an unlinked system, as well as linked systems in which the exchange of data between with the travel model was done at varying intervals. Although they have used it for regional planning studies, it has never been used specifically for transit evaluation. HGAC differs from other locations in that they run a separate UrbanSim model for each of eight counties, which is done to permit tight control over county control totals. In that sense, the model is calibrated at the regional/county level, but not at smaller geographic subdivisions. In addition, HGAC has maintained a larger grid cell (1,000-foot) grid cell system, which is roughly double the grid size used by other UrbanSim installations. They do not have full documentation of the system, but have provided spreadsheet tables from its database listing parameter values. If asked, HGAC would be very happy to participate in a case study, although they would prefer to upgrade to UrbanSim4, which they are planning to do in the coming year. HGAC also has a lengthy wish list of improvements they would like to make to the system, including moving to a parcel-based system, redefining development types and adding building types, developing a separate redevelopment module, and differentiating between owners and renters and different housing types, and merging the eight counties into a single model.

Contact: Dmitry Messen

WFRC

WFRC began integrating UrbanSim3 into their daily operations in 2004 and now use it to produce land use forecasts on a routine basis. The model covers both the counties served by WFRC and adjacent counties served by the Mountainland Association of Governments (MAG). Early on, WFRC devoted a good deal of in-house staff time to making custom modifications to model specifications and minor program coding changes in order to develop a model system that produced reasonable forecasts. One of the issues they addressed was inflation resulting from the hedonic pricing model. As simulated time progressed in the model, accessibility to population and employment grew at a rate that was not proportionally diminished by travel impedance. The model runs annually and exchanges data with the travel model at one-year intervals, with land use data maintained using one-acre grid cells. These accessibility calculations caused average land prices in the model to increase at a rate of four percent annually, while incomes remained in constant 2000 dollars. WFRC remedied this by changing the form of the land price model by adopting land price ranges as the dependent variable in their model, essentially creating a categorical choice model.

Most recently, WFRC applied the integrated model system for the "Wasatch Choices 2040" visioning process that was used to help develop the "2007–2030 Regional Transportation Plan." This visioning process was a collaborative planning effort, which included representatives from WFRC, MAG, Utah Department of Transportation, and Utah Transit Authority. Within this process, UrbanSim was employed as an analytical tool to compare multiple land-use and transportation scenarios in a manner consistent with urban growth theory. WFRC also used UrbanSim as one tool in developing population and employment projections by traffic zones for input into the long-range planning process; however, they have not used UrbanSim to analyze a specific project alternative. WFRC considers the land use model to be calibrated at the county level and is now undergoing a more rigorous calibration process for subregions. A peer review panel recommended that the model not be used for corridor-level planning until this is done. WFRC would be willing to participate in a case study if selected, and has provided technical documentation on their model specifications.

Contact: Andy Li

6.5 URBANSIM4/OPUS

Developer: Center for Urban Simulation and Policy Analysis, University of Washington (Paul Waddell and Alan Borning)

Type: Disaggregate, Disequilibrium, Dynamic, Transportation-Linked

Installations: Southeastern Michigan Council of Governments (SEMCOG)

Puget Sound Regional Council (PSRC)

San Francisco County Transportation Authority (SFCTA)

AZ SMART – Maricopa Association of Governments (MAG) and Pima Association of Governments (PAG)

Description

The fourth generation of UrbanSim began in 2006 and retains most of the features of UrbanSim3, described above, but also differs in important ways. First, UrbanSim4 was developed in the OPUS environment ("open platform for urban simulation"), which featured a move to the more user-friendly Python scripting language and the ability to estimate discrete choice and linear regression models embedded into the program structure. In addition, OPUS makes it possible to develop new model structures relatively easily.

Important structural changes to UrbanSim4 included the switch to building types rather than more generic development types as a scheme for classifying land and developer decisions. This was viewed as a theoretically superior approach and offers users more flexibility in tailoring UrbanSim to unique local real estate conditions.

Another important structural change was the design of a more flexible system for organizing land information spatially. This has enabled recently developed models to use parcels rather than grid cells, potentially improving resolution, and allowing use of varying sizes of land units within the same model structure.

Status

SEMCOG

SEMCOG implemented one of the first versions of the UrbanSim4 model in 2006. The model has been linked to their trip-based travel model and can be run interactively. They consider the UrbanSim model to be consistent within a "limited calibration" standard in that they have adjusted the regional control totals to obtain results more closely aligned with their official forecasts by county. Thus far, the model has been used for greenbelt proposals and alternative land use plans, primarily focusing on Washtenaw and St. Clair Counties, but has not been used for transportation analysis. The model specification follows the standard UrbanSim specification, but has not been extensively documented. SEMCOG would need to compile these data and would do so upon request. In addition, they are not willing to participate in a case study at this time, citing the need to protect the confidentiality of ES202 employment data.

Note: UrbanSim4 includes an embedded model estimation routine in which users can estimate discrete choice and linear regression model coefficients directly from the system database and have the resulting parameter estimates placed directly into the model application tables for immediate use. While this has made it extremely convenient for the users to rapidly develop and implement models, it seems to also have resulted in a reduced effort to document model specifications.

Contact: Guangyu Li

PSRC

PSRC has been in the process of implementing an UrbanSim4 model for the past three years and has worked closely with the University of Washington in providing data to improve the overall design of the software. The UrbanSim model has been integrated with PSRC's trip-based travel model, but has yet to be used in any official travel model applications. Plans for later this year are to incorporate it into a new activity generator/trip-based model, now under development. PSRC has spent considerable time calibrating the model for runs spanning the years 2000 to 2006 and believe that the model is now ready for regional analysis. In 2009, they plan to work with planners from local jurisdictions to do a more rigorous calibration; however, the current level of calibration is at the regional level. PSRC currently is using their integrated UrbanSim/travel model to support its transportation plan update for 2010. They have not yet used the integrated modeling system for any transit projects, but the five alternatives all have differing levels of transit levels of services, including new LRT, commuter rail, ferry, and bus services. This modeling will occur over the next two months for five alternatives and the baseline used in the plan.

PSRC's UrbanSim/travel model also is integrated with a new benefit-cost analysis tool which produces benefit and cost metrics for analysis of economic value. PSRC has chosen to select additional evaluation criteria directly output from UrbanSim to determine how the integrated models do in terms of growth management and economic development metrics. PSRC would be pleased to participate in a case study and feel that this will support their efforts to further the integrated modeling system (including UrbanSim, travel model, and benefit-cost analysis tool). PSRC also has indicated that they might be able to run the models for the study team, suggesting that the hardware and software necessary to run these are more than a typical system. A draft model technical report was completed in June 2008, but a more final version has not been completed (due to workload). The current report does not include model specifications. PSRC runs UrbanSim annually, with the travel model running at five-year intervals. The current application for the transportation plan update process may vary from this slightly to save on processing time, but these details have yet to be worked out.

Contact: Maren Outwater

SFCTA

SFCTA implemented an UrbanSim4 model in spring 2008, and produced good results at an aggregate level. Due to staff workload priorities, however, the project was put on hold until October 2008, after which the calibration and validation process was restarted with a target completion date of January 2009. The UrbanSim model has been designed to be used in concert with SFCTA's tour-based model system, SF CHAMP, running at five-year intervals, but has not been adopted for official use yet. The San Francisco City Planning Department provides the official land use and socioeconomic forecasts for use in the SFCTA model system; thus, it is this department that will determine acceptance. The current focus is on getting forecasted growth to allocate to the right places, which has been challenging due to San Francisco's unique real estate market and the relatively constrained geographic scope of the model. Following land use calibration and validation, the plan is for more integrated testing with the travel model, focusing on comparisons with the most recent RTP forecasts. An initial set of model parameters was estimated using the embedded logit estimation utility in OPUS, with significant help from the University of Washington. Documentation of model parameters is not ready for distribution. SFCTA would not be willing to participate in a case study in the near future until such time that the City Planning Department is comfortable with the land use forecasts.

Contact: Billy Charlton

AZ SMART

AZ SMART, the joint land use model development project between the MPOs serving Phoenix and Tucson, Arizona, is now in its second phase of development. The development team has completed most of the database development for the MAG and PAG areas and has begun model estimation. Consequently, AZ SMART is not able to participate in any near-term case studies, with full implementation tests likely to occur in late 2009 or early 2010. Nonetheless, this project is one to watch as it differs markedly from the others in its geographic scope and scale. The idea behind AZ SMART is to recognize the gradually merging market areas of the two MPOs by developing a joint land use model that both agencies can use for their individual planning studies, with a consistent set of assumptions and some shared travel data. Another salient feature of this model is that the results of the UrbanSim model will be post-processed at the parcel level. The initial plan called for UrbanSim forecasts at a grid cell level, with suballocation to parcels using a proprietary program called SAM-IM; however, now it appears that SAM-IM will be used to post-process parcel-based UrbanSim results in a final allocation step, which still needs to be fleshed out. SAM-IM has been used by MAG for several years in its land use forecasting practices in conjunction with DRAM/EMPAL and is viewed by the agency as very reliable. It consists of a rule-based process for subarea allocation added on to GIS software (ArcView and Spatial Analyst).

Contact: Anubhav Bagley, MAG

7.0 Summary of Findings on Model Structures

The derivation of economic development benefits of transit projects from integrated land use transportation models is complicated. The review of the various model systems described in this report has lead to several potentially helpful observations. The implications of these observations for the ability to model the impacts of transit projects are discussed in Section 8.0.

- There are widely varying ways in which accessibility is measured in integrated land use transportation models:
  - Regional or subregional accessibility to jobs or households based on composite travel costs – access to markets;
  - Trip-weighted measures of regional accessibility based on composite travel costs – the cost of commuting;
  - Access to opportunities within a predefined buffer – walk access to markets;
  - Proximity to transportation system nodes – access to highway interchanges, arterials, and airports;
  - Unweighted composite travel times to all other zones;
  - Access to central business districts; and
  - Access to employment of the same or complementary industry type at the regional, subregional, or local level – agglomeration effects.
- All of the model systems reviewed employ some type of discrete choice model for location choices, although there are significant differences in their underlying decision theories, with three primary variations emerging:
  - Travel-oriented linkages between workplaces and residences – a multidimensional choice context applied at the aggregate level, although there is no reason this could not be developed for individual households;
  - Economic flows between businesses and households and between other businesses – essentially an aggregate allocation model; and
  - Disaggregate choices of autonomous agents – individual household and business choices of location and land development decisions.
- Variation in the representation of how land prices are derived generally takes one of two forms:
  - A top-down approach in which land prices are calculated, usually iteratively, as a shadow price for balancing supply and demand within a zone; and

  - A hedonic regression equation composed of location-specific attributes and used in the utility function of separate location choice models.

- Likewise, developer decisions are modeled in one of two ways:

  - At an aggregate level in which more land is put into production as long as it is profitable and taken out of production if it is not; and

  - As agent-based, responding to changes in land values and accessibilities at the local level, incrementally.

8.0 Usefulness of Current Integrated Land Use Transportation Models for Evaluating Transit Projects

Table 9.1, which appears at the end of this document, summarizes the current status of the integrated land use transportation model systems reviewed in this report. In terms of the case study potential of the model systems, there are four primary items of concern that may limit the usefulness, or at least the readiness, of this set of models for the purposes of evaluating the economic development benefits of transit projects.

With the exception of MetroScope, the current set of land use models had not been calibrated or validated below the regional level.

Calibration at the regional level simply means matching regional target values, which are usually exogenously determined controls on the model outcomes, and in most of the models reviewed, are matched automatically. Below the regional level, allocating the right types of development, households, and employment to the right locations is considerably more difficult. Not only do the residential and commercial location choice models lack calibration constants, but the two models also compete in many places for the same alternatives, units of land (e.g., mixed use), and their outcomes are interwoven through the variables specifying the regional accessibility to households and jobs, as discussed above. Further, unlike a travel demand model in which the supply side of the equation in the form of network capacity is fixed exogenously, in a land use model, supply in the form of urban residential and nonresidential structures is endogenously determined, responding to the demands of households and businesses, and is a capacity-constrained resource that may be consumed only once during a modeled year. An additional consideration is that the model may be relatively accurate in portraying location preferences, but the pace of development and the rates at which households and businesses move may be asynchronous.

When comparing land use model results to observed totals at the subregional level, calibration essentially involves looking for plausible location-specific attributes that are not reflected in the current specifications to determine how to best revise them. Options for respecification include redefining household, employment, or land use/development types (resegmenting markets); respecifying variables used in utility functions or linear equations; or constraining choice sets. In addition, controlling the timing of development may involve the more straightforward exercise of adjusting developer response timing as well as household and commercial "mover-stayer" response rates to better reflect local conditions.

As just one example, it was recommended that future enhancements of the OMPO UrbanSim model include redefining development and building types so that they more closely resemble location-specific land uses; namely port facilities, resorts, tourist-attractions and tourist-oriented retail, military bases, and agricultural land uses. Without these changes, employment in the industries that should be concentrated in these particular land uses will be scattered to unrealistic locations elsewhere in the region. Another example, which highlights the need to consider path dependence, is the recognition that households of similar sizes tend to collocate in the same neighborhoods, as is the case with families with children versus singles, and which might be handled by specifying lag variables in the location choice utility functions. Another tactic is to constrain choice sets, such as the allowable transitions between one land use type and another, or constraining allowable locations for the placement of employment of a certain industry or households of a certain type. Very restrictive constraints, however, may not be desirable in all scenarios. Other problems are more difficult to diagnose and mend, such as the failure to account for spatial autocorrelation in model estimation, which may lead to nontrivial parameter misspecification, a particular issue for models using small spatial analysis units such as parcels and grid cells. As a last resort, a few locations within the modeled region may be so idiosyncratic that an argument may be made for the use of a location-specific constant, the land use modeling equivalent of a k-factor.

As described above, the PECAS model installations are being calibrated in stages, by moving from very aggregate zone systems to finer zone systems. Because they are based on the spatial I-O model concept, subregional calibration across all model components is intimately tied to the zone system design at each stage. This would seem to add an additional layer of complexity to the process, although there are undoubtedly advantages to working through certain calibration tasks at a relatively high level.

Some agencies, including WFRC, OMPO, SFCTA, and PSRC, have begun to closely examine district-, corridor-, and even neighborhood-level benchmarks, but none of these agencies has expressed confidence that the models they now have are ready for analysis at these levels. An important difference between Metro and these other agencies would seem to be staff resources. MetroScope was developed completely in-house, with a full-time staff of three to five persons assigned to its operation and refinement (about 1.5 to 2.0 FTE) for 10 years. The other agencies reviewed here have had their models developed for them by consultants, most of them more recently, and do not have staff who can be dedicated to running their models and resolving calibration problems. PSRC has only recently added a staff position for this purpose.

In addition, to date, there appears to be no transit project evaluation experience using the current operational models, although some have been used for RTP studies for which transit was a part. This is due in some agencies to the original purpose of the model systems being the analysis of regional growth management policies, and is reflected in the lack of transit-specific attributes in model specifications.

In the specification of regional accessibility measures, transit impedance is either not included at all, or is integrated into a composite travel cost based on mode choice log-sums.

As described in the first section of this report, there are many ways in which regional accessibility may be represented in land use models, and the developers of the models have chosen specifications that seem to work well for general purposes. None of the models reviewed in this report use transit travel times and costs directly as a measure of impedance in calculating regional accessibilities. In fact, MetroScope currently is specified and calibrated to use auto travel times and uses a fixed mode choice model in order to save computational time.

The other model systems reviewed here use mode choice model log-sums as a measure of composite costs which, if properly specified, should include transit system generalized costs as a component. As comparative statics, log-sums are a theoretically valid way to gauge differences in the accessibility provided by transit across scenarios; however, they must be specified carefully to include the right modes for the context. Mode choice log-sums used in the accessibility calculations should be stratified by household auto availability levels, and specified in household location choice utility functions accordingly, which has been done in the UrbanSim model specifications but may be have been overlooked in other model systems. This does not really help, though, with the accessibilities used for nonresidential location choice, forcing an assumption of a mean or representative level of auto ownership when specifying log-sums.

In addition, there is a potential endogeneity problem in that auto ownership and residential and workplace location choices are interrelated decisions, requiring that land use and transportation model systems be tightly integrated through feedback mechanisms. A model system that fixes mode choices or any one of these longer-term decision components in order to save computational time is likely to produce inaccurate estimates of the contributions of transit to accessibility.

There is little to no specification of variables needed to measure transit-station-area effects, transit walk access, park-and-ride facilities, tax policies, or transit-supportive land use plan changes, although all the models would seem to have the potential to include such variables.

As discussed above, a significant benefit of fixed-guideway transit is its effect on surrounding land values, and its success hinges in large part on station access, which should be represented in location choice and hedonic pricing models. Further, any tax policies (e.g., subsidies) or transit supportive land use plan changes (e.g., zoning) that might accompany a transit investment scenario will be location-specific and therefore could be included as attributes of land units and subsequently used as variables in choice models.

That current model specifications lack these attribute variables would seem to be an oversight that could be remedied easily by their inclusion and model re-estimation. At a minimum, walking distance to a transit station must be included as a land unit attribute. Other more specific station-area amenities and parking facility capacities also could be created as a land unit attribute and should be specified in location choice models and in hedonic pricing models. Development impact fees and subsidies do appear in MetroScope and also should be factored into the development cost and profitability calculations made by other models such as PECAS and NYMTC LUM. Known installations of UrbanSim to date have not included development costs in developer choice models, which would seem to be essential for the purposes of transit-supportive policies. Transit-supportive zoning changes also would affect developer decisions and should be represented as a change in the choice set constraints on allowable development types and densities, a seemingly straightforward task.

Some models may be too spatially coarse and therefore insensitive to transit impacts on accessibility, land values, and development.

It is a well-known problem among travel models that large zone sizes make it difficult to obtain accurate estimates of nonmotorized travel within or even between adjacent zones. To address large zone-size problems, various heuristics have been developed to estimate what percentages of zones have access to transit stations. Some of the integrated land use and transportation models reviewed in this report, namely PECAS and MetroScope, utilize zone systems that are far coarser than those used by their linked travel models. Reasons given for using coarser zone systems are mainly related to the fidelity of the input data (e.g., census tracts and employment data sources) used to construct and calibrate the models, although there also are computational advantages. When these coarser zone systems are then used as location choice alternatives, they inherit accessibility attributes from an underlying travel model operating at finer resolution. This presents a problem as to how to represent the regional accessibility of these larger zones, whether to use a representative TAZ or some blended value of constituent TAZs.

In terms of local accessibility, such as walk access to transit or presence of parking facilities and potentially other amenities, a problem exists that is similar to travel models in which it may not be clear how to calculate walk access travel times or whether to attribute a qualitative factor to all or part of a zone. Moreover, larger spatial units, even grid cells, require the modeler to generalize land use definitions in order to roughly approximate actual zoning designations as was initially developed for UrbanSim. In MetroScope and PECAS, land use is expressed in percentages of each building type category. This could be problematic for the inclusion of transit-supportive land use and tax policy variables because they may apply to only a portion of a zone. A drawback of these blended or proportional approaches is that the larger the zone size, the less relevant these attributes become for the utility of the zone as a location, which could seriously dilute the ability of the model to estimate their benefits.

A third aspect to the large zone size problem is that the supply of developable land in a zone may not necessarily be close to a proposed transit station, making development less likely to occur despite the presence of the transit station in the same zone. By the same token, different types of development are likely to occur at different distances from a transit station, and a large zone size will not be able to capture these differences.

9.0 Recommended Enhancements

As discussed in the previous section, the current generation of integrated land use transportation models is severely limited with respect to their ability to measure the economic development benefits of new transit projects, either at a regional or localized (i.e., transit-related development near stations) level. Consequently, FTA should not expect to obtain quantitative, comparable measures of economic development benefits for evaluating New Start applications without significant enhancements to these models. We recommend the following enhancements to make current integrated land use transportation models more sensitive to transit improvements as a necessary first step in evaluating economic development benefits. Recommendations are listed in descending order of priority, both in terms of importance for FTA's New Starts program, and in consideration of the level of effort required to implement the recommended enhancements in current integrated land use transportation models.

1. It is recommended that FTA's consideration of the economic development benefits of transit projects focus on changes in land use related directly to accessibility, rather than on secondary outcomes such as land values, job creation, or increasing the tax base. Accessibility is what integrated land use transportation models seem to measure best. Therefore, changes to the composite utilities of location choices would seem to be the most consistently measured and theoretically supported way to evaluate the value placed on accessibility, and is consistent with user benefits measures already used by FTA.

2. At a minimum, regional accessibility variables used in land use models must incorporate transit impedance. Models that rely solely on auto travel times or generalized auto costs to measure regional accessibility are inherently insensitive to improvements in transit level of service, and therefore cannot be expected to measure the development impacts of transit projects. The most straightforward method for incorporating transit impedance into a regional accessibility measure is to use the log-sum variable from the mode choice travel model, and to allow feedback between the land use and travel models, enabling the log-sum variable to change in response to changes in mode share between zones.

   The impact of incorporating transit impedance in a regional accessibility measure is likely to be small for most areas, given the overwhelming dominance of auto use in regional mode shares. But for those zones where transit use is significant, the regional accessibility measure may be able to capture the effects of a major transit service improvement, and provide at least a lower bound on economic development benefits.

3. For the purposes of evaluating transit projects, the geographic units of analysis utilized in the land use models should be no larger than the transportation analysis zones (TAZ) used in the travel forecasting model, and preferably should be smaller, down to grid cells or parcels. It should be conceptually straightforward to develop and apply residential and employment location choice models at the most disaggregate level possible, while maintaining a more aggregate zone system for calibration and validation purposes, much like the practice in travel modeling of using district-to-district movements to help calibrate trip distribution models.

   By maintaining consistency between the geographic units used in the land use and travel models, localized improvements in transit level of service will be retained in the land use model rather than diluted by averaging them over a larger geographic area.

4. While transit improvements are likely to have only a modest impact on regional accessibility, the most significant economic development impacts are likely to occur in the immediate vicinity of new transit stations. To effectively measure these localized impacts both land use and travel models need to be enhanced to provide more detailed resolution of travel behavior and land use development around transit stations. These enhancements include:

   – Better representation and modeling of walk trips, both as access to transit and as intrazonal trips. Models should consider the effects of improved pedestrian amenities (e.g., sidewalks, shelters, reduced conflicts with autos) and the amount of mixed use development on destination and mode choice.

   – Better representation of mixed-use development in land use models, and especially those factors that encourage or inhibit mixed use development.

Considerable research has been done on the interrelationships of urban form and travel behavior (e.g., the effects of density, design, diversity, and distance on nonmotorized and transit trip making), but relatively little of the knowledge gained from this research has yet been incorporated into travel demand forecasting or regional land use models.

As a first step toward an objective assessment of localized economic development benefits that could be used in evaluating New Starts projects, FTA should undertake a research and development effort to develop procedures and tools to better model the relationship between urban form and travel behavior in the vicinity of transit stations.

Table 9.1 Summary of Integrated Land Use Model Installations Surveyed to Date

Metro Area	Platform	Typology	Implementation Status
Portland	MetroScope	Aggregate, equilibrium, static, transportation linked	Calibrated at subregion, used in growth management.
New York	NYMTC LUM	Aggregate, equilibrium, static, transportation embedded	Calibrated at region level, not used.
Sacramento	PECAS	Aggregate, disequilibrium, dynamic, transportation embedded	Not calibrated, possible implementation test 2009.
San Diego	PECAS	Aggregate, disequilibrium, dynamic, transportation embedded	Not calibrated, possible implementation test 2010.
Baltimore	PECAS	Aggregate, disequilibrium, dynamic, transportation embedded	Not calibrated, timeline not available.
Honolulu	UrbanSim3	Disaggregate, disequilibrium, dynamic, transportation linked	Calibrated at region level, not used.
Houston	UrbanSim3	Disaggregate, disequilibrium, dynamic, transportation linked	Calibrated at region level, used in RTP.
Salt Lake City	UrbanSim3	Disaggregate, disequilibrium, dynamic, transportation linked	Calibrated at region level, used in RTP.
Detroit	UrbanSim4	Disaggregate, disequilibrium, dynamic, transportation linked	Calibrated at region level, used in growth management studies.
Seattle	UrbanSim4	Disaggregate, disequilibrium, dynamic, transportation linked	In final throes of calibration and testing, used in RTP.
San Francisco	UrbanSim4	Disaggregate, disequilibrium, dynamic, transportation linked	Now in calibration, more testing in 2009.
Phoenix/Tucson	UrbanSim4	Disaggregate, disequilibrium, dynamic, transportation linked	Early stages of development, possible deployment 2009-2010.